[redacted]

THE THOR-AGENA STORY

draft prepared by

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Contents:

Chap 1 - Introduction

Chap 2 - Thor Adaptation

Chap 3 - Agena Development

Chap 4 - Launch, Flight, and Recovery

Chap 5 - Agena D

Chap 6 - Thrust Augmented Thor

Chap 7 - Conclusions

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Chapter 1

INTRODUCTION

Since the close of the Second World War American military services have been activiây interested in earth-circling satellites. Pertinant German reasearch came to the attention of American military personnel and under the sponsorship of the Army Air Forces, the RAND Corporation undertook feasibility studies of earth satellites. In September 1947, [redacted] an Air Force preliminary study + evaluation of RAND reports revealed that a satellite was technically feasible, and in 1948 the Air Force, as an independent service, requested RAND to establish a program for the further investigation of possible satellite development.[2]

During the next few years, RAND studied the problem under the code name Feedback. By 1954 RAND reported that a space vehicle could be placed in an earth orbit by a rocket powered booster. RAND personnel recognized that numerous system component development problems existed but such hardware development would not require radically new technology or enormous costs

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1. Ltr, TSEON(TSEON-1) [redacted] Circa Dec 1947 from Ch Engr Div Brig Gen Allen R Crawford to CofS

2. Ltr, Maj Gen Crawford to Douglas Aircraft Co, Aug 17, 1948, subj: Satellite Project

[redacted]

About the time RAND was completing its study, the Air Force established a research and development program on an advanced reconnaissance system, [redacted]. The Wright Air Development Center, Dayton, Ohio, was responsible for managing the program called Project 1115. Air Force personnel made intensive feasibility studies including such critical component development areas as satellite-born electrical power for equipment operation and component reliability in a satellite enviornment.

By 1955 the Air Force had obtained sufficient data to insure that the problems were surmountable. which permitted system design studies to begin. Consequently, in that year, Wright center awarded design study contracts to Radio Corporation of America, Glenn L. Martin Company, and Lockheed Aircraft Corporation for the purpose of determining if a [redacted] recommaisance satellite system could be developed within a [redacted] time span which would warrent a full seale development effort.

These "Pied Piper" studies [redacted] submitted by all three contractors showed that the system could be developed.

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[redacted]

With these positive reports, the Air Force felt that it could begin hardware development under the title WS 117L.

The Air Research and Development Command believed that it would be best for Western Development Division located in the Los Angeles area to manage the program. The Los Angeles division managed the ballistic missile top national priority program, and since the WS 117L system would have to use a missile as the first stage booster and the change of location was an attempt to remove potential military satellite areas of conflict between the two programs. During 1956, management functions passed from the Wright center to the missile division.

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[redacted]

[redacted]

Personnel from both Wright center and the Los Angeles division combined their talents in the preparation of a WS 117L development plan. In May 1958 Washington authorities including Secretary of the Air Force Donald A Quarles, and the President's Science Advisory Committee generally approved the plan.

The plan called for a two stage vehicle which could be launched from United States territory. The booster or first stage would be an intercontinental ballistic missile which would fall away when the engine burned out at about 3,000 miles from the launch pad. The second stage would be the orbiting vehicle, which would have a propulsion system to supply the necessary power to propel the vehicle into a speed necessary for orbit. The vehicle would ascend to an altitude of about [illegible] miles where an orbit would be assumed, and internal controls would orient the vehicle in the proper attitude.

[redacted]

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[redacted]

Meanwhile im March 1956, an Air Force board convened at Wright center to study the Pied Piper designs and to recommend a contractor for hardware development. The board recommended Lockheed as the prime systems contractor and this action was subsequently approved by the Department of Defense. The Air Force formally awarded the contract to Lockheed's Missile and Space Division at Sunnyvale, California on 29 October 1956.

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[redacted]

[redacted]

The development plan had specified $32.1 million for fiscal 1957. However, despite the program's high national priority, there was a chronic shortage of funds during the ensuing twelve months. The Defense department had already planned its fiscal 1957 budget and consequently there was a time lag while the budget was juggled. [redacted] The first funds finally arrived on the West Coast in December 1956, but only in the amount of $3 million. Subsequently, during the year, this amount was incrementally increased to a total of $18.9 million. The Western Development Division made repeated efforts to relieve the situation with no appreciable results.

Of greater importance was the extremely conservative approach Assistant Secretary of Defense Quarles to the entire program. He would not authorize the fabrication of mock-ups or experimental vehicles. He wanted the development to continue at a slow pace, to be conducted along conventional lines, with an initial flight target date some time after 1 January 1960. Aside from the [redacted] about the usefulness of a military satellite, there was concern over the possible political repercussions arising from the use of a military

[redacted]

ROUGH DRAFT

[redacted]

space vehicle.

~~As a matter of policy no mock up or experimental vehicle was to be fabricated without Douglas permission. During this time period no approval~~

The fund limitation and the defense department's general attitude caused WS 117L program activity to be channeled into component rather than total system development. On a short supply of funds, ~~During the pre-Sputnick~~ Lockheed began satellite airframe design studies, investigated sources for satellite-born auxiliary power and attitude contol systems, and selected a satellite propulsion systems which would be available at an early date. Indeed some tehhnical progress was made but of equal importance a contractor team had been assembled and a broad base established from which rapid expansion could grow.

(based largely on hist rpt, WS 117L, Jan-Dec 56; short hist & chronology WS 117L, 1946-1959)

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[redacted]

Acceleration

In July 1957 the division (renamed Air Force Ballistic Missile Division on 1 June 1957) submitted two new development plans during 1957. The first, which specified that if the current level of funding continued, September 1959 would be a realistic target date for the first launch. However, a more desirable level of funding—$67 million for fiscal 1958 and $142.5 million for fiscal 1959—would enable a first launch in March 1959. The Air Force Council recommended the "desirable level" of funds, but before the Department of Defense gave approval, the Soviet Union launched Sutnik I on 4 October causing political and emotional repercussions. would have to be launched under a new Secretary of Defense.

A few days later, the following Air Force secretary James H Douglas approved the "desirable level" and Air Force headquarters released part of the 1958 funds to the division. When the new defense secretary Neil McElroy was briefed on 29 October 1957, he was so enthusiastic that he directed the immediate release of the balance of the 1958 funds and that the program proceed as rapidly as good management would permit.

ROUGH DRAFT

[redacted]

[redacted]

Also during the crisis atmosphere following the first Sputnik, both RAND and the Department of the Air Force urged that Thor boosters be used in conjuction with the planned Lockheed 117L upperstage to provide an early space demonstration. In addition two special advisory groups created to consider steps for reviving United States prestige arrived independently at the same conclusion.

In February the Secretary of the Air Force asked for approval of a program acceleration based on the expanded use of Thor-boosted satellites, but a decision was delayed pending the activation of the new Department of Defense's Advanced Research Projects Agency. The overall management of the WS 117L program was to be one of the task of the new agency. On 28 February, the new agency's director Roy Johnson approved the Thor-117L combination for early flight tests and as a means of conducting biomedical experiments.

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The principal obstacle to WS 117L acceleration remained fund[illegible]g. Not until June 1958 were the various proposals and counterproposals reduced to an approved program. At that point, the Thor-WS 117L phase

ROUGH DRAFT

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received enough money to support the fabrication of the first 12 vehicles. By this time, thetotal 117L effort was under the new agencyis control, the Secretayy of Defense gradually making the shift between February and June.

During December 1958, the Advanced Research Projects Agency divided the original WS 117L program into three specialized projects, two of these included the Atlas as a booster and the other retained the [redacted] Thor.

The Thor boosted program involved space engineering test functions, biomedical experimentation, development of recovery techniques, and associated military support activities.

Eleven months later, on 17 November 1959, the Secretary of Defense transferred the Thor-Agana (as the second stage began to be called) to the Air Force. However, for any program changed, [redacted] the Air Force Ballistic Missile Division would have to receive approval from the Department of Defense Director of Development, Research and Engineering.

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[redacted]

[redacted]

The Thor-Agena, booster-satellite combination represented an early and major Air Force achievement in that it was the first hardware combination to progress to almost routine launchings and payload recoveries. Although each stage was used with other space hardware combinations, the Air Force used the two stages together for flight tests more frequently than any other combination. The original Thor-Agena flight proposal was 5 in January 1958, increased to 10, 13, 15, 19, and then 25 flights by 30 April 1959. Shortly after the first complete flight sucesses, --launch, orbit, and capsule recovery--a new production growth began in August 1960. The approved total moved upward from 35 to 41, then to 44, 60, and 65 by July 1962. Of comparable or greater importance, Director of Development, Research and Engineering in October 1961 had authorized indefinite continuation of production to provide adequate numbers of Thors and Agenas for a variety of space projects.

Defense ?

(based largely on USAF Space Programs, 1945-1962)

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[redacted]

Chapter 2

THOR ADAPTATION [redacted]

In November 1955 the Department of Defense assigned the development of the Thor 1,500 mile intermediate range ballistic missile to the Air Force. By the end of the year the Air Force's Western Development Division ~~had solicited Ramo-Wooldridge to perform system engineering and technical direction and~~ had let a letter contract with Douglas Aircraft Company to development the airframe, assemble the various systems, and test the entire package under the technical direction of Ramo-Wooldridge. With the back log of experience gained during the early development of the intercontinental ballistic missile, and with the decision to use components and facilities under development for the longer range missiles, the Thor development time was greatly lessened. In fact, just fourteen months after the contract award, flight tests began at Cape Canaveral, and they continued until February 1960 after 48 Thors had been expended perfecting the [illegible] and all component parts. Actually the [illegible] which eventually came to be used in the Thor booster had gained considerable early experience in [illegible] special reentry vehicle tests and other satellite launches.

ROUGH DRAFT

[redacted]

[redacted]

Guidance

[redacted]

For intercontinental ballistic missiles the Air Force had let two contract in 1955 for development guidance systems. AC Spark Plug Company--a subsidary of General Motors--was developing an all-inertial system and Western Electric's Bell Telephone Laboratories was to develop a radio-inertial system. [redacted]

After the Thor became part of the Air Force missile development program, there was no immediate decison on which guidance system to apply to the short (120m) range missile. However, after a series of program changes ending in May 1958, the Air Force Ballistic Missile Division definitely assigned the AC Spark Plug to the Thor and the Bell system to the early Titan combat squadrons.

However, the AC Spark Plug system would not be ready for flight tests until November, while Air Force planners had scheduled some Thor development flights between June and October to carry the Bell system.

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[redacted]

The necessary ground equipment for the radio-guidance would be ready at Cape Canaveral and [redacted] since there was no interference with the AC Spark Plug system development, the Air Force allowed the schedule to [redacted] stand.

Beginning in July 1958 there was a series of three lunar probe ~~space~~ launches from Cape Canaveral using the Thor as the first stage booster.but without a guidance system. All three were failures [redacted] primarily due to instability in ~~the propulsion system~~ Thor Engines rather than due to [redacted] inadequate guidance.

In the meantime, the Air Force Ballistic Missile Division was making plans for the first Thor-117L launches from Cooke Air Force Base. later Vandenberg Air Force Base.
By September 1958, the division had definitely decided not to use any of the unproven guidance systems and to rely on the Thor's autopilot and electronic programmer. (contr -65, sup 15, amend 1, 29 Sep 58)

~~During 1959 the development of the AC Spark Plug system continued [redacted] and after all improvements were incorporated, the system weighed 1,300 pounds.~~

[redacted]

ROUGH DRAFT

[redacted]

But when this decision was made, the guidance systems were still under development. Developers gradually decreased the missile-borne weight of the radio-guidance system, while the inherently heavier all-inertial system gained more weight. By the end of 1959 the operationally configured Thor guidance system weighed 1,800 pounds. Bell had reduced the systems weight to 140 pounds for use in four successfully guided reentry vehicle tests during first half of 1959. The same configured system was used in Titan flight tests beginning in February 1960. The Bell system also contributed to the successful launch of a Thor boosted satellite from Cape Canaveral on 1 April 1960.

At Vandenberg, As part of the Titan program, the Air Force had established two launch installations each with one radio antenna and computer. However, by January 1960 one of these installations was abandoned and consequently, the ground guidance equipment was available for other programs.

By July 1960, Bell had made additional improvements in the airborne components [redacted] consisted of two canisters weighing a total of 80 pounds. In order to improve and increase the reliability of the booster's programmed trajectory, the division decided to use the system in the Thor

ROUGH DRAFT

[redacted]

Propulsion

For the Atlas missile, the Rocketdyne Division of North American Aviation Company was developing two booster and two vernier engines with thrusts of 150,000 pounds and higher for each booster and 1,000 pounds for each vernier. In early 1956, the Air Force directed Rocetdyne to adapt one of the booster engines and the two vernier engines for use in the Thor missile. Recketdyne was to deliver the required engines to Douglas, who was responsible for their installation in the missile frame. For flight tests Douglas received the first 150,000 pound thrust engine in January 1957. During the following twenty months Rocketdyne made improvements including an integrated start system and made extensive Douglas received for tests. A The first operationally configured engine [redacted] for flight tests in November 1958.

However, during previous static and flight tests revealed difficulties particularly in the turbopump. Reocetdyne found solutions and incprporated them into another designed engine [redacted] which was ready for flight tests beginning in April 1959. As part of available Thor Missiles, both these engines helped boost Agenas into orbit. Although the Thor weapon system program office was [redacted]

ROUGH DRAFT

contractors had proposed further engine development with a goal of increasing the thrust to 165,000 pounds. [redacted]

Although these 150,000 pound booster engines met the requirements of the Thor weapon system program, space programs were interested in a higher thrust engine. By April 1959 the Air Force Ballastic Missile Division established a requirement for a higher 165,000 pound thrust engine. Following static tests and three succesful flight tests during January and February 1960, the improved engine-- LR 79-NA-11-- was available for use in Thor space boosters.

The 15 Thor engines had been calibrated to burn RP-1 fuel, but in an effort to increase the paylaad capacity of the Thor-Agena, the division in mid-1959 decided to switch to the RJ-1 fuel. This fuel Rocketdyne had developed the fuel for the Navaho ramjet engine. RJ-1 was quite similar to RP-1 except that it was denser and had higher energy qualities. Captive tests using the LR79-NA-9 engine had indicated that the fuel would increase the velocity of the booster by a matter of seconds, but a study of flight data in January 1961 showed that there had been no significant advantage in using the RJ-1 fuel. Nevertheless, the Air Force continued to use the denser fuel for the Thor-Agena launches and Rocketdyne calibrated LR79-NA-11 engines for RJ-1 consumption. [redacted]

ROUGH DRAFT

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Missile Production

Just prior to Sputnik, the Air Force headquarters had authorized a total proudction of 175 Thor missiles at a rate of two per month. If this programmed had been followed, the first operationally configured missile would not have been ready before November 1960. (STL final rpt)(TWX 14 Aug 58)

However, following Sputenik, the Air Force trippled the planned production rate, reduced the number of research and development type missiles, and set a goal of June 1958 for the delivery of the first operationally configured missile. In making these revisions the Air Force cut the number of missiles to be produced back to the bare essentialls for the Thor program, a total of 147. (STL final rpt; TWX 2 Dec 57)

On 6 January 1958, General Schriver appealed to the Air Force Chief of

[redacted] ROUGH DRAFT

Staff to reinstate 24 missiles [redacted] ram in order to accomplish objectives not directedy related to the Thor weapon system program. Stc (ltr 6 Jan 58) Such objectives included tests of re-entry vehicles, early demonstrations of an intercontinental ballistic missile capability and possible space launches. Under Secretary of the Air Force Malcolm A MacIntyre approved the additional missiles and authorized an increased production rate of eight per month beginning in November 1958. (memo 31 Jan 58; TWX, 7 Feb 58)

Within another year and half, Washington authorities had allocated a total of 64 Thors for "special purposes." and/authorized a production rate of nine missiles per month beginning in February 1959, extending through September 1959, and then tapering off to four per month from beginning in February through October 1960 when the last missile would roll off the assembly line. (STL final rpt)

Since February 1958, the Air Force had planned on activating four Thor squadrons of 15 missiles each in the United Kingdom. In addition, late in 1959, Washington had directed the Air Force Ballistic Missile Division to protect the capability of activating a fifth squadron with ten missiles. On 23 February 1960, the Air Force headquarters canc[illegible] t[illegible]ir[illegible]t, but not until after most of the missiles had started [redacted] assembly l[illegible] division had to allow

ROUGH DRAFT

[redacted]

a minimum of twelve months for a Thor to pass through the line.

So, the division had another ten missiles that could be made available for space programs.

With the termination of Thor development at the end of 1959(except for engines), the Air Research and Development Command transfered the executive management responsiblity to the Air Material Command. The Air Force Ballsitic Missile Division cancelled the system engineering and technical direction role held by Space Technology Laboratories, a subsidary of Ramo-Wooldridge, contracted with Douglas for system engineering, and retained technical direction for itself. (Wky Dispatches, 3 Sep 59, 29Oct 59)

ROUGH DRAFT

[redacted]

For these early [redacted]space launhces, the Air Force had Douglas take a missile off the assembly line and mad[redacted] as neccessary to meet the required program. However [redacted] in November 1959, technicans [redacted] established a specdification for a Thor booster which would be based [redacted]. All [redacted] produced. This was known as the DM-21 missiles frame. The principle difference between the booster frame and that of the operational configuration was that the transition section where the AC Spark Plug Guicance System was located was shortened by five feet. The space prgrammers were not using a guidance section (?) so a long body was not needed and it improved the aerodynamic capability of the combined launch system. Sinde Rocketdyne's LR79-NA-9 and LR79-NA-11 engines were interchanegable [redacted] from one missiad frame to another, the dontractor could install the 165,000 pound thrust engine in DM-21s to meet program requirements.

ROUGH DRAFT

[redacted]

[redacted]

In Februayy 1960, the Secretary of Defense approved the fiscal year 1960 reasearch and development program. [redacted] and Air Force headequarters directed the Air Force Ballistic Missile Division to produce fourteen more Thors to boost Agenas into orbit. (TWX 27 Feb 60, justify 16 Mar 60; TWX 28 Sep 60)

Consequently the division was able to contract with Douglas to begin production of the DM-21s. However, the authority limited the production to two per month, so the con tract specified production would begin following the last missile configured Thor and extend through May 1961. (contr -24)

ROUGH DRAFT

[redacted]

[redacted]

During 1960, space program requirements continued at

to exist perhpas in larger degree than during the previous year.

By December 1960, Washington had increased the number of Thor-Agena

flight from 24 in late 1959 to 41. In the meantime, if the Air Force

production line was to continue, Washington would have to authorize

additional procuement (TWX 27 Oct 60) Indeed Washington responded

with an authorization ofr four more DM-21 boosters.

(TWX 28 Nov 60) After the Thor office had made presentations

to the Air Research and Development Command headquarters

the Air Materiel Command headquarters and the Air Staff,

(ltr 12 Dec 60)

asking for permission to procure 48 more missiles, Washington approved

an additional procurement of 12 at a continued production rate of two

per month. This December authorization would keep the Thor assembly

line busy through February 1962. (TWX 30 Dec 60)

ROUGH DRAFT

[redacted]

[redacted]

During the ensuing months there was a constant struggle between the Space Systems Division and Wahiggton authorities over the continued production of Thor boosters. At first the division objected to the low production rate of boosters, principally because the unit cost would be higher and the confidence that there would be a demand for the product. The division learned to live with the low ppoduction rate but the real difficulty lay in obtaining early enough Washington approval so as not buase a break in the production line. Otherwise the division feared that it would be costly in time and money to have to start the production line going again. For orderly production and contract negotiations the division needed to know of 15 months in adavnce of the when the first booster would be delivered. In practice however, this lead time was more nearly ten months due to the late approval of Washington authorities.

ROUGH DRAFT

Washington authorities did not want to approve the procuemant fo more boosters than there was [illegible] of using. Often the program office in the space division using had a difficutl time obtaining Washington program approval and adequate funds. (TWX 11 Aug 61)

[redacted]

[redacted]

The space division usually procured the boosters [redacted] with reimbursable funds; that is, the Thor booster office [redacted] had an alloted [redacted] fund for [redacted] direct procurement and the using program offices would pay the Thor office at an established rate. (Maj Young interveiew 29 Jan 63)

The net result of this [redacted] continuous dialogue between [redacted] Los Angeles and Washington was that upon each request for authority to continue the product on line there was a [redacted] minimum [redacted] authorization. (TWX, 31 May 1961)

ROUGH DRAFT

[redacted]

[redacted]

After urgent requests from the Space Systems Division, on 13 March 1961, the Air Force headquarters authorized the procurment of four additional boosters, on 30 March, six more, in July, four more, in September, three more, in October, five more, and in December, eight more booster at the rate of two per month continuing booster production well into the middle of 1963.

(ltr 14 Mar 61; TWX 30 Mar 61; TWX 30 May 61; TWX 6 Oct 1961; ltr 13 Nov 61; contrs- 55 and -80)

ROUGH DRAFT

[redacted]

Standardization [redacted]

When the San Bernardino Air Materiel Area assumed executive management responsibility, the material area also assumed responsibility for the configuration control board. (ltr 28 Jan 1960) in November 1959. Since during 1958 and 1959, the Air Force was pulling missiles off the Douglas assembly line and modyfying them to configure to the desired requriement, a standard was not appropriate.

But there was already the beginnings of standardisation with the design of the DM-21 late in 1959. In August 1961, the Air Force approved a new acceptance specification applicable to those boosters coming off the assembly line beginning in March 1962. (hist rpt 26 Feb 62; contr -887)

The advent of the acceptance specification coincided with an effort to standardize the internal subsystems of the Thor booster. The Space Systems Division felt that standardization would reduce production costs, and increase reliability. An example of standardized systems efforts was the control electronics assembly which consisted of an autopilot and programmer.

ROUGH DRAFT

The booster control electronics assembly had essentially been a modified missile flight controller, which required modifications for the various space booster configurations. (ltr 25 May 62) [redacted]

[redacted]

In May 1961 the division determined that the electronics assembly needed standardization. and in response to the division's request, Douglas provide the Air Force with a prototype. The contractor then modified the assemblies in stock before undertaking the manufacturing of any new ones. (ltr 20 Jul 61; contr 0887, amend 1, 24 Jul 61; contr-887-80 , 5 June 62)

By mid-1962 the division had completed standardizing most of the subsystems which the division thought should be changed.

Even after these changes were incorporated into the stanadrard booster, some differences would continue to exist. These result from the use of various second stages which differ in their dimensions, and methods of firing and seprating, and the location of the guidance sys[redacted] (hist rpt 26 Feb 62)

ROUGH DRAFT

However, the idea was to be able to support as many programs as feasible with as few changes as possible. [redacted]

[redacted], The Space Systems Division felt that in order to retain standardized components a configuration control board was necessary. In April of 1962, the division established such a board chaired by a Thor booster office representative and consisting of representatives from National Aeronautical and Space Administration, each Space Systems Directorate having a direct interest in Thor space booster configuration, and appropriate Air Force Plant Representatives. (ltr, 2 Apr 62)

ROUGH DRAFT

[redacted]

Originally the [redacted] intermediate range ballis[redacted] was developed and deployed as an interim solution until the longer range intercontiental missiles could be readied for combat within the United States. In Washington authorities publicly announced that Thor intermediate range ballistic missiles were no longer needed and would be gradaully withdrawn from England.

DDR&E directed that these SM-75 missiles be converted into DM-21 boosters at Douglas' inactive plant at Tulsa. Space Systems Division negotiated a contract with Douglas for the conversion of the first squadron (15 missiles) and work began in November 1962. San Bernardino Air Materiel Area was responsible for the refurbishing of the MB-3, Block I engines. The boosters were to be converted at the rate of two per month with the first completed late in February 1963. Space Systems Division estimated that the modification price of each booster would be $275,000.

(notes, fSSD program review, 14 Nov 62)

The Space Systems Division had estimated the average price of new boosters procured under Air Force letter contracts since 1 January 1960 at $192,000 (based on ltr 30 July 1962: this is the price payed to Douglas at Santa Monica [illegible] not include [illegible] engines, BTL guidance units, or Douglas launch services.)

ROUGH DRAFT

[redacted]

[redacted]

This announcement was the beginning of the end of the Thor as a ballistic missile and the future use of Thor exclusively for space purposes was on the horizon. In retrospect, the transfer of executive management responsibility from [redacted] Los Angeles to San Bernardino on 1 January 1960 may be considered a watershed in Thor history. Before that date 160 Thors were under contract for development tests, operational squadrons, and crew training launches, while only 64 had been earmarked for use as first stage boosters for reentry vehicle tests and space launches. During this early period, the Air Force had the missile frames modified for what was at that time "special purposes", but beginning in 1960, all Thors placed on contract were assembled as a booster, in most instances meeting the specifications of the DM-21, sometimes called the Standard Launch Vehicle.

ROUGH DRAFT

[redacted]

Chapter 3

AGENA DEVELOPMENT [redacted]

The fact that the Air Force had designated Lockheed Aircraft Company as prime contractor for the 117L program did not mean that Lockheed was to perform research and development, design, manufacture and test of the many system components. On the contrary, the Air Force expected Lockheed to procure most of the component parts including entire subsystems from capable and experienced firms who performed tests on their product before delivering it to Lockheed. These subcontractors were to dleiver the tested hardware to Lockheed which in turn would integrate the components, subassembleis and subsystems into an integrated upper stage and would be respensible for the system tests together with those of the subcontractors. (ltr 23 Sep 57)

During 1957 someone conceived of the Santa Cruz Test Base, a Lockheed property for research and development vehicle, propulsion and component testing. [redacted] conceived of the idesa of acceptance firing of [redacted] thus requiring additional equipment and instrumentation. (ltr 11 Apr 60)

ROUGH DRAFT

[redacted] [redacted]

Lockheed produced the early flight test vehicle in various locations. The contractor fabricated components at the Van Nuys plant, assembled the vehicle at Sunnyvale, modified installed and checked out subsystems at Palo Alto, then shipping the vehicle for engine firing and system checkout to Santa Cruz. (Prog rpt 31 May58) (Mar 59 Q)

The Air Force planned that Lockheed's 4,000 acre tract north of Santa Cruz be used for static firing and a complete systems checkout of the entire vehicle. (Presentation on Santa Cruz) (Dev Plan Mar 58)

The Air Force simulated $400,000 in industrial engineering work. Workers completed the components test laboratory in April 1958 and finished the two static firing test stands and blockhouses two months for testing of the first flight vehicle in August 1958.

(Prog Status rpts, 15 Apr 58, 30 Aug 58)

ROUGH DRAFT

Early in planning fo the program, a deicision made to fabricate two propulsion test vehicle assembles [redacted].

~~Two failures occured in September 1958 minor ones (Sept 58)~~

For the first flights, Lockheed [redacted] vehicles to Sunnyvale for further checkout, then to Vandanberg where in an assembly building the vehicle under went further chnecks, and then still further checks onthe pad prior to laucnh. During 1960, the Air Foec Ballistic Missile Division made an effort to cut down on some of these chanks and consequently expenses.

~~The division [redacted]~~

These proceddures were not only expensive but also costly. The division attempted to reduce/or eliminate the need for checkout procedures at Vandenberg assembly building and at Santa Cruz.

During this period of time, the biggest oblstacle in accomplishing a cut back in testing and chekout procedure was the simple fact that no two vehicle were alike. However, during this period Lockheed was able to produce a series of vheicles which were alike, therefore only the first

ROUGH DRAFT

of a series needed to be tested at Santa Cruz. (ltr 12 Dec 60)

In addtion the extensive chekcout of the vehicle at the Vandenber aseembly buidling was eliminated. ((16 June 1961)

The various Air Force program offices usually installed their payloads in the Agena in the assembly buildng. [redacted]

Following the award of the 117L contract to Lockheed Aircraft Corporation, the prime contractor began making design studies for the second stage seatellite vehicle including the necessary subsystems. and casting about for possible subcontractors to develop these subsystems. Lockheed concluded that perhaps a pump-fed propulsion system would technically be the best, but type of propellant other factors such as the availability of a particular engine and the competance of the particular firms producing the engine. should be considered.
(L 31 Jan 57, p 5-6)

The Bell Aircraft Company had been developing a turbo-pump rocket engine for the air-to-ground missile which would be carried by B-58 Hustler aircraft then underdevelopment. By March 1957, Lockheed with the concurrace of the Air Force, selected Bell's IR-81 engine as the basic propulsion unit for the 117L's second stage. (Spc Proj) (Wkly Diary, 28 Mar 1957)

Later, during the year the Air Force cancelled the missile portion and following the engine's preliminary flight rating tests of the B-58 program, [illegible] about $570,000 worth of hardware [illegible] transferred to the 117L program.
(*(As part of the B-58 development program, Bell had been a subcontractor under Convair at Ft. Worth)
(Wkly Diary, 117L, 22 Aug 57 and 14 Nov 57)

ROUGH DRAFT

ROB Project Card, DD Form 613,
Project Cover Sheet Computer for AFS, WS 117L,
Project No 1756, Sub. No. 2-117, 2 Apr 1957

[redacted]

[redacted]

The LR-81 engine consisted of a single thrust chamber, gas generator, inluding starting solid propellant charges (ullage rockets), turbine driven pumps, propellant control valves, and auxillary equipment to start operate and shut down. (2 Jul-Sep 56 pp 17-20; Turb 3 Apr 58?)

Without interfering with the ballistic missile program, the final selected engine was the only available with a turbopump feed system and within the required thrust range. The LR-81 engine had a trust rating of about 15,000 pounds. [Engineers felt that the control system without an additional system.] The engine burned JP-4 fuel when combined with the oxidizer inhibited red fuming nitiro acid. (RDB Proj Card, DD Form 613 Propulstion Subsystem, 2Apr 57)

From the B-58 design For the B-3 engine, the [redacted] engineers made only a minor change which increased the propellant burning time from 65 to 100 seconds.

ROUGH DRAFT

[redacted]

[redacted]

During 1958 Washington changed some of the flight objectives although the principal ones, satellite vehicle and ground communications remained the same. The secondary objective, The development of visual reconnaisance including film recovery, was replaced with the development of a recoverable capsule and the collection of geophyscical data for research purposes. In March, the directive said that the new requirement would become effective with the fifth flight, however, before the end of the year it had been changed to be effective beginning with the third flight. In order to meet the new objectives, the satellite vehicle would have to manuever with a heavier load than had been originally planned.

(30 Jun 58; July 58; Dec 58 Q)

ROUGH DRAFT

[redacted]

[redacted]

Meanwhile, contractor engineers had been study the possibility of improving the propulstion system in order to cayyy a heaveier payload in flight. (L Jan-Mar 58, p 1-9) In March the Air Force directed Lockheed to proceed with the nexxary work to changexxx the propulsion system design and the fuel. Lockheed Engineers recommended a slightly heaveir and higher energy fuel, ~~Technicals decided to use~~ unsyemtrical deimthal hydraznie.

I" addition the relative sized ~~xxxx~~ of the engine combustion throat and nozzle extension ~~injection~~ mouth would be increased from approximately 1 to 15 to 1 to 20. (L Apr-June 58, p 2-39; Wkly Diary, 27 Mar 58)(15 Apr 58 rpt) TWX 3 apr 58

A slight increase in the size of the aluminum propellant tanks and rearrangement of the plumbing resulted in a slight lenghtening of the overall airframe. (Jun 58 rpt; L Apr-Jun 58, p 2-25)

ROUGH DRAFT

[redacted]

[redacted]

For ground tests, Bell delivered two engines to Lockheed in March 1958. By June, technicians had mounted them on the two newly completed propulsion test assemblies at Santa Cruz. The entire propulsion system composed of prototype components underwent generally successful hot firing tests. At the same time Bell was conducting a series of flight rating tests at its own plant. The firing at both locations were completed by August, but Lockheed continued testing the propulsion assembly's plumbing with the fuel and oxidizer throughout the remainder of the year.

L J-1158 p 2-32

In June 1958, Bell shipped the first two flight test engines to Lockheed at Sunnyvale. Lockheed assembled these engines with the other subsystems and components to form the first two flight test vehicles. Following modification and checkout, the two vehicles arrived at Santa Cruz. At the base the two vehicles successfully passed the hot firing tests with all flight equipment installed and operating. As a [redacted] both vehicles at Santa Cruz, [redacted] for final adjustments before flight, hopefully before the end of the year.

Weekly Diary of Chas 8 Spec Prop 1 Jul 31 Dec 58
" " " Chas 8 1 Jan 31 Dec 58
24 26 Nov

ROUGH DRAFT

L Apr 1958 pp 2-39, 2-40
1174 Report Jul 58
Sep 58

[redacted]

[redacted]

Technicians erected a prototype propulsion system and began flow tests with the new fuel. Performance was within specifications and therefore Bell completed assembly ing the first unsymetrical dimethal hydrazine flight engine and delivered it to Lockheed in September 1958. (Sept 58) Although propellant temperature variations were initially troublesome, Bell solved the difficulty and then began rating tests. The new engine designated LR81-Ba-5 was rated at 15,600 pounds of thrust compared to the XLR-8 engine with 15,150 pounds. In addition, /The new engines could burn almost twice as long, 120 seconds compared to 64 for the old. (Ltr Aerojet 58 P 2-25 14 Dec 58; Mar 59 + one more)

By September 1959, Lockheed had incorporated the new engine into fourteen flight vehicles.

At Santa Cruz, pre-acceptance testing of satellite vehicles continued with There were in turn shipped to for which included hot engine firings, inspections, and functional component checks. After incorporating any engineering changes, the Air Force accepts the vehicle. (Sep 59)

ROUGH DRAFT

[redacted]

Agena B [redacted]

Early in 1959 developers began changing the satellite propulsion system to such a degree that the end product was known as the Agena B and the previous configurations, by way of contrast, the Agena A.

In flight, Agena A engines were dead once the propellant was extinguished, but technicians began working on a scheme whereby an engine could be restarted in response to a signal from the ground. The concept originated when a program needed a higher orbit than the current Thor-Agena combination was capable. (ltr Feb 59, AFBMD Space Apr 61) The booster was capable of useless

By the first of March 1959, the Air Force Ballistic Missile Division had set July 1960 as the goal for the new engine's first flight test. (ltr 15 Jan 59, memo 6 Mar 59) The Advanced Research Projects Agency approved the development on [redacted] and also directed that the propellant capacity be increased. (ARPA order 17-59, Amend 4, 10 Apr 59) By August engineers had decided that tanks with double the Agena A capacity would be the best with both Thor and Atlas boosted flights. In order to accomodate the new capacity, designers added six feet to the length of the cylindrical mid-section of the Agena. When applicable Engineers used components and materials proved in the Agena A and subjected the new design tank to similar ground tests such as including vibration and centrifuge tests. In addition Lockheed will build a new propulsion test [redacted] at Santa Cruz incorporating the new design.

ROUGH DRAFT

[redacted]

Early in the year the AirForce Ballistic Missile Division had determined that the restart engine tests would be conducted at Arnold Engineering Development Center as well as at Bell's facilities. Tests at Arnold would include those in the high altitude chamber. (Hr 15 Jan 59) Necessary testing on the new engine called LR81-Ba-7 had already begun by the time the Advanced Research Projects Agency issueded formal approval and in September 1959 Bell shipped one engine to Lockheed for testing in the new propulsion test assembly.

By 1 March 1960, Lockheed had received all flight engines of the new configuration, had completed tests of the new propellant tank design, and had shipped the first assembled Agena B to Santa Cruz for tests. During the Santa Cruz tests certain difficulties had to be overcome including redesigning the helium regulator propellant valve. Before Air Force acceptance, technicians had to rework three engines and repeat the systems tests. (Jan Feb 31 Mar 60) Under different circumstances, Bell began an extensive series of reliability tests at its own plant, which would have ensued, but due to the limited number of flights which would employ this particular engine model, by June 1960 the Air Force decided in June 1960 to terminate further testing, by Bell.

ROUGH DRAFT

[redacted]

Nevertheless, tests had confirmed that the LR81-Ba-7 had the same thrust as the previous Agena A model--the LR81-Ba-5--, but with twice the burn time ---four minutes. (MSP Mar 60)

[redacted]

The limited number of flights scheduled for this radically new model was that, meanwhile, engineers had been concurrently improveing the capability of the Bell engine by another approach. The approach was to increase the relative size differences between the throat-ired and the mouth. In July 1959, the Air Force Ballistic Missile Division authorized Lockheed to proceed with such improvements in the LR81-Ba-5; (ltr 31 Jul 59; TWX 28 Jul 59) however, in March 1960, the first dual restart engine--LR81-Ba-7,- was undergoing acceptance testing. At that time the AirForce directed that no further effort be expanded on improving the Agena A model, but apply that work toward improving the new restart engine.

After several months of testing, the Air Force specified that mouth of the new model should be 45 times larger than the throat. (ltr 15 Feb 60; contr -247 CCN 36 25 Mar 60) The greater the size differences, the greater the speed across the throat and the greater the force exerted against the nozzle extension.

At both Bell's facilities and at the Arnold center technicians tested nozzle extensions made of graphite, steel, and titanium. (MSP Dec 59, 31 Mar 60) Titanium proved successful for [redacted] but the throat eroded. The erosion was curtailed by coating the throat with abrasive materials such as [redacted] Zirconia. (31 MSP Apr 60) Testing and evaluation of throat coatings continued into June.

ROUGH DRAFT

[redacted]

In September, technicians completed the preliminary flight rating tests without appreciable nozzle throat erosion (MSP Q Nov 60). The new LR81-Ba-9 combined an increased thrust---16,000 pounds with a restart capability. (AFBMD Space Apr 61)

Earlier in the year, Beal had shipped an "expanded nozzle" engine to Lockheed for testing in the propellant test assembly at Santa Curz.

Hot firings ~~of the Ba-9 were in~~ progress of during Feburay and March 1960, ~~at Santa Cruz.~~ This series consisted of nine firings ancldding several restarts. One of the prime objectives was ~~the parts of the program was~~ the testing of a fuel-powered hydraulic system to gimbal the engine which performed satisfactorily (Feb 60; Mar 60)

In orbit the restart of a gimballed engine would ~~to~~ propel the vehicle into another flight path.

ROUGH DRAFT

[redacted]

[redacted]

Although technicians were not completly satisfied with test results, Bell shipped the initial "expanded nozzle" engine to Lockheed for flight vehicle (June 60) In June 1960. After being assembled with the other airborne components and hot fired at Santa Cruz, the Air Force accepted the vehicle in August 1960. (Aug 60)

In order to further test the engines reliability, technicians continued tests at Bell's facilities and at Arnold.

At Bell the engines were operated in various positions and under unsual vibration frequencies. (Oct 60) The use of a fuel with a high solid content tested the skin temperature of the thrust chamber.

At Arnold, tests simulated altitude and temperature conditions in which the engine would operate in orbit. (Jan 61, Feb 61) The Air Force considered the reliability tests--60 in all--to have been completed in April 1961.

The tests demonstrated an engine operational life far in excess of the specified requirements. (Apr 61) MSP Q May 61)

ROUGH DRAFT

[redacted]

[redacted]

Chapter 4

LAUNCH, FLIGHT, AND RECOVERY

America's military services were using Cape Canaveral for missile flight tests and spade programs and the Air Force had orginally planned to launch 117L satellites from there.

Following Sputnick, not only did the Department of Defense authorize the use of Thor as a booster in the 117L program, but also approved peacetime missile launches from the West Coast at Cooke Air Force Base (later renamed Vandenberg) (TWX 23 Nov 57)

The Air Force had selected the base for the first operational intercontinental ballistic missile force, but with permission for peacetime launches the Air Force could use the base also for complete integrated weapon system tests and combat training launches of both intermediate and intercontinental range. Also, early in 1958 the Air Force decided that the Thor booster 117L satellite should be launched into polar orbit, and considering overflight hazards, a southward launch from Cooke would be the best procedure.

ROUGH DRAFT

[redacted]

[redacted]

At Cooke the Air Force had reserved an area near the ocean for Thor launch installations. At first the Air Force planned for only one launch complex consisting of a launch control blockhouse and two launch emplacements or pads. As program requirements increased, the Air Force added a second complex, and then upon the "polar orbit" decision, a third complex was added for the 117L. (WKly Diary / WDI 28 Feb 58) 25 Apr 58)

The Air Force dsigned the first two complexes for test and training activities including the launch of missiles in a westerly direction. The third complex was designed to launch the two stage combination southward in 182 degree azimuth.

As the Air Force's construction agent the Corps of Engineers had begun work on the first Thor launch facilties in the fall of 1957 and as decisions were made in regard to the other facilities, the corps' activities expanded. Like the 117L program the Thor weapon system program required a West Coast launch emplacement [illegible] at Cooke and [illegible] efforts were made to have [illegible] at the test complex and one at the 117L complex by the needed date. Other installations could be completed later. (Ltr 9 Jul 58) The Air Force accepted pad 4 and the blockhouse from [redacted] 21 August 1958, [illegible] (Weekly Diary WDI Installation) 22 Aug 58

ROUGH DRAFT

[redacted]

In the meantime ground equipment for pad 4 had been arriving at Cooke since May and workers began emplacing the equipment as soon as the area was clear. (Wkly Diary 22 May 58)

[redacted]

About the same time the corps had completed separate facilties to house Thors and second stage vehciles after their arrival on the base until thier emplacement on the launch pad.

[redacted]

In these facilities Air Force contractors installed inspection, maintenance, and checkout equipment. The first vehicle arrived from Lockheed in November 1958. and Thors from Douglas began to arrive for both missile program purposes and space launches.

ROUGH DRAFT

[redacted]

[redacted]

In the meantime, Air Force teams were wandering around the United States and the Pacific Ocean choosing sites for satellite tracking and data acquisition stations. The Air Force chose sites and had established temporary facilities and equipment at points in Hawaii, And Alaska by August 1958 (Terhune files, installations) 22 Aug 58)

The [redacted] one at Ft Lawton, Washington, in the northwest United States and one at Ottumwa, Naval Air Station, Iowa.

The Air Force decided that data and tracking stations were needed in the areas of the United States, northwest, central, and northeast. These stations gradually came into operation. Fort Stevens was approved for the northwest, Ottumwa Naval Air Station, Iowa for the central, and for the northeast at New Boston, New Hampshire.

ROUGH DRAFT

[redacted]

To gain as much information as possible about [redacted] hardware behavior on each flight, the Air Force utilized one or two ships equipped with special telemetry equipment. [redacted]

m (L vol 2)

The need for certain type of information was greater on some flights than on others and the ships were numbered to the locations where the need was greatest. On the early flights the Air Force was primarily concerned about getting an Agnea into a suitable orbit.

After orbital injection seemed to be mastered, the Air Force became increasing concerned over the ejection of the recovery capsule, and

To gather information on orbital ascent, a ship moved to a position downrange about 1,000 miles. To gather information on ejection and reentry procedures, ships were located between Alaska and Hawaii.

ROUGH DRAFT

[redacted]

Due the many takks that needed to be preformed, contractors began preparing for a launch se[redacted] for the shheduledliftoff. Among these tasks were the transporting of the first and second stages from their respctive ~~fax~~ checkout facilities to the launch emplacement. They were mated together in a horizontal position, but~~xdaxfax~~ the crew did not ascend the gantry until the day of the launch.

At best procedures for a launch lasted ~~fxxm~~ more than severn hours. Preaparations for the launch usually began in the pre-dawn hours when the crew mated the recovery capsule to the Agena and raised the Thor-Agena to an erect position. ~~It took several hours for~~ For several hours the crew ~~[redacted]~~ checks the radio freqencies, makes umbilical connections including the propellant lines, warms up electronic equipment , loads the propellant tanks with fuel, checkout guidance and flight control systems

The last 15 minutes were devoted almost excludively to the Thor. Then when the missile automatically passes through a sequence of fueling, calibration, ar[redacted] and [redacted]. However, ~~in case of a technical malfunction or~~ ~~The count~~ However, ~~any case, a countdwon may be held~~ Clearing the process up until pp until the the last five seconds, ~~befnce liftoff,~~ the countdwon may be held for the crew may be held either for technical reasons, to allow a train to pass, or due to ~~inclement~~ weather conditions.

ROUGH DRAFT

(Look 1)

[redacted]

[redacted] Workers had readied pad 4 for the first launch and had assembled a modified Thor and Agena for a launch on 21 January. During countdown procedures smoke began to rise while explosions occureed in the Agnea and Launch personnel cutoff the power immediately. ~~Ground power caused ingnition of the ullage rockets inaventently and safety circuit failed.~~ Apparently the ullage rockets had accidently fired and triggered off internal mechanisms causing serious damage to both the first and second stages.

Follwing removal of the hardware from the pad, technicians determined that the Thor could be repaired for a future launch. but the Agenax was not worth rehabilitating. Technicians investigated the accident to determine in detail the causes so corrective measures could be taken prior to the nest countdown. (mo rpt Jan 59; L vol 1)

[redacted]

ROUGH DRAFT

[redacted]

[redacted]

Two weeks later,
Technicians gava the next Agena a completem systems check test in the assembly building on 4 Feburay and then transproted the vehicile to the launch pad. The launch crew mated the Agena to the Thor and conducted a practice countdown on 19 February. The crew made an attempt to launch the combination on 25 Februry but after twelve hours of countdwon procedures, the managers decided to postpone the launch so that corrections could be made in the Thor's liquid oxygen tank pressurization system. A second attempt was successful on 28 February. when the Thor-Agena combination zoomed off into the mid-day sky. As programmed the Thor rolled into a southernly direction, the Agena separted from the booster and began coasting in a polar orbit. Radar at Vandenberg and Point Mugu and telemetry tracking equipment at Vandneberg received signals from the Agena for more than eight minutes after liftoff. Although ground equipment [illegible] not confirm [illegible] over the Pacific area, sporodic signals acquired on later pasees showed that the vehicla was in orbit. The Air Force considered this launch ax success. (mo rpt Feb 59; L vol 1)

ROUGH DRAFT

[redacted]

[redacted]

By Feburary, the Hawaiian control center was prepared and combination air and sea forces were ready for recovery ~~xxx~~ operations. (mo rpt Feb 59; ~~xx~~ L vol 1.)

In order to align flight with the current Thor-Agenaed program, the Air Force decided to consider the January abortive countdown as the first flight test. (mo rpt Feb 59) Since the program specified without recovery capsules, only two JPL propelled Agenas A the next flight would ~~xxxx~~ include a second stage ~~xxxxxxx~~ which ~~xxxxx~~ would burn unsymetrical dimethal hydrazine/(Q rpt Mah 59) and carry a recovery capsule. This time the crew launced an Agena into orbit ~~xxxxxxxxxxxx~~ at the end of the first countdown.

Immediately after Agena engine burnout the satellite stabilization and guidance system operated a series of small gas jets which caused the vehcile to turn 180 degrees in a horizontal plan so that the satellite was floating in orbit with engine in the forward position and the recovery capsule ~~xxxxxxxxxxxxxxx~~ forward. The new position was in preparation for the seventeen ~~xxxxxxxxxxxxxxx~~ from the earth the satellite nose would tilt 60 degress downward ~~from the~~ to permit the ejection of the reentry ~~xxxxxxx~~ capsule. Telemetry data showed that that control and ejection equipment operated properly

ROUGH DRAFT

[redacted]

[redacted]

The Air Force has established a groudd-communication system after computing the orbital period afound the earth so that ~~from the ground~~ a nrothern ~~ground station~~ tracking station, could adjust the vehicle-born timer ~~in the~~ so that ~~the timer would activate~~ interx on the seventeenth pass the timer would react at the correct moment so ~~could on a later pass and from a ground signal~~ that the recovery capsule woutl be injected a predicted area. ~~could be activated~~

However, the Agena had gone into an orbit at a low velocity which cuased ~~the~~ the orbital period to much shorter than ~~what~~ what was expected. There resulted some confusion in the ground tracking station and the ground command made an error in resetting the timer.

(L vol 1) The ~~reset~~ reset error, introduced ~~from~~ into the satellite timer from the ground, made it impossible to adjust capsule ejection to perment impact within the planned recovery area.

~~Automatic ejection took place. Based on the automatic ejection~~

Technicians ca[redacted] ~~the capsule would impact on the orbital circle.~~ near the Norwe[redacted] ~~effort~~ by both air and ground American and Norwaign forces failed to find the capsuel although local observers had sighted ~~whatex~~ what was thought to be ~~the US Air Force interpreted as~~ a descedding parachute and foil chaff.

ROUGH DRAFT

[redacted]

[redacted]

Telemetry and radar [redacted] installations in the satellite continued to operate extremely well through the twenty-fifth pass which was about one and half days after launch. A continuous wave beacon imeted signals for another week and [redacted] reports of visual sighting continued until 25 April when the Air Force estimated that the satellite reentered the earth's atomphere and burned up.

In the meantime, the Air Force took steps to prevent [redacted] an ejection from taking place [redacted] above the [redacted] geographic area. Tracking procedures were revised [redacted] and the vehicle timer was repalced by a more sophisticated one manufactured by Fairchild. (Q rpt Jun 59) no rpt apr)

ROUGH DRAFT

[redacted]

[redacted]

On 7 May 1959 the first and second stages were moved from their respective housing and checkout facilities to the launching pad where mating and complete systems checkout occured. In addition the Air Force installed a Mark I recovery capsule on the top of the Agena. However the combination was on the pad for several weeks due to several abortive countdown sequences. Threesdelays were cuased by technical difficulties, two in the Agena and one in the Thor. (L vol 1)

Finally on 3 June the crew completed a countdown with a launch which was to end in dismal failure. The launch itself, ascent, vehicle separation, Agena coast, and engine boost were accomplished as planned. However, the Agena's LR81-Ba-5 engine shut down prematurely causing the vehicle to fail to acheive the required orbital velocity. The second stage fell into the Pacific south of the equator.

ROUGH DRAFT

Three [redacted] launched a similarly configured combination with this time with only one abortive countdown. However, the results were as heartbreaking as the previous one.

Due to two seemingly similar failures of the Agena and the result loss of thousands of dollars [redacted] ment and time, the Air Force

[redacted]

Ballistic Missile Division postponed the [redacted] next scheduled flight and initiated and investigation of the failures. Studies showed that [redacted] better performance could be obtained by an increase in [redacted] decrease in satellite weight.

Studies showed that the last two flights did not achieve sufficient velocity at the time of second stage burnout to obtain orbit.

[redacted]

Technicians had first believed that the engine had shutdown prematurely; however, this postmortum investigation revealed that in both flights that the satellites had not acheived sufficient velocity at the time of second stage burnout. to obtain orbit.

The Air Force approved several actions taken in order to improve the situation. Lockheed reduced the weight of the Agena by 48 pounds by removing desirable but not essential equipment and instrumentation. Space System Division was hoping that the Thor velocity could be improved by as much as 200 feet per second with the use of RP-1 fuel instead of the standard RJ-1. In addition, the Air Force directed that the launch azimuth be changed from 175 to 170 degrees. This slightly more easterly direction would take advantage of the earth's rotation and increase the Agena's speed [redacted] was expected to provide an additional 200 feet

ROUGH DRAFT

[redacted]

~~pe[redacted]~~. (mo rpt Jul 59) Launch equipment had be ba adjusted for the new direction. Launch emplacement number 5 ~~[redacted]~~ had been completed for the fourth flight, launch, so there were two pads available for space launches.

~~The fifth flight [redacted]~~

The Thor-Agena combination had been waiting on launch pad 4 for several weeks before final launch on 13 August. There were a total of five postponments, four times due to poor weather conditions and a fifth due to a Thor engine ingnition failure. Finally on 13 August the crew launched the Thor-Agena into the sky and after separtaion the second stage achieved an orbit. Tracking and data acquisition at all ground stations was excellent this time.

A Thor-Agena had been installed on pad 4 and the launch crews did not ~~[redacted]~~ encounter such bad luck, only one postponement, the ~~fixx~~ sixth flight [redacted] and achieving orbit [redacted] only six days following the other. Tracking and data acquistion was generally good at all ground stations except Point Mugu and Vandenberg wherer radar interference was experienced. [redacted]

ROUGH DRAFT

[redacted]

On both of the August flights all objectives were acheived except capsuel recovery. ~~On both flights~~ Kodiak and Hawaiian data from tracking stations indicated that capsule ejection occured between the two; therefor e near the planned point. However tedemetry from the fifth flight indicated that the low capsule temperature was lowqr than expected and ~~xffxx~~ prevented the ~~xxxxxxxxxx~~ parachute-opening mecanism from operating. On the sixth flight difficulties with the command-timer-adjustment sequence delayed the capsule ~~xx~~ ejection 360 miles sough of the planned point. During both flight the sea and air recovery forces were deployed properly in relation to the expected impact point. But due to the last minute changes only aircraft were able to reach the ~~xxxxxx~~ revised impact areas. ~~xxxxxx~~ beforethe capsule would normally sink ~~in~~ beneath theocean wawes. ~~Thexxxxxxxxxxxxxxx~~ The forces only received scattered radar dignals from the fifth flight's ~~xxxxxx~~ capsule and nothing from the sixth flight's. (mo rpt 31 Aug 59)

ROUGH DRAFT

[redacted]

[redacted]

August
Due to the failures of these two/recovery attempts,

the Air Force postponed additional flight until an detailed

evaluation and testing of the entire recovery system could be made.

In order to allow for ~~xxxxx~~ improved retro-rockets to be incorporated

in the next flight/configuration, the Air Force ~~xxxx~~ delayed the

launch unitl 3 November. (~~xx~~ mo rpt, Oct 59)

on pad A four
However, ~~xxxxxxxxx~~ abortive countdowns delayed a launch~~xxxxx~~ for

actual
four days. The/launch and orbit acquisition was a complete success

but between that time and the first pass over ~~xxxxxxx~~Alaska, the Agena's

battery
~~xxx~~ auxilary powers ~~xxxxx~~ failed, ~~inactivating the guidance system~~

~~The power failure.~~ The operation of the guidance system, the horizon

scanner/ and gyro stabilizers, depended on that power, so consequently

Crews also found it impossible to activate
the vehcile began to tumble. ~~By the second pass the~~
~~xxxxx~~ the recovery capsule ejection seqience.

small
~~the/jets which stabilize~~ ROUGH DRAFT

(L vol 1) ~~Maintenance~~

from and 5
a Two weeks later on ~~the neighboring pad~~ A technicians ~~successfully~~
placed an Agena into orbit without the
~~launched the eighth Thor-Ible Thor Agena. This attempt was not marred~~
accidents having occurred previously. (MBP Q Dec 59)
with any abortive countdowns.

[redacted]

~~He~~ ~~the Agena~~

[redacted]

However, the Agena ascended into orbit ah a greater speed than pppgramed. Lockheed had installed a mechanism, called the accelerometer-integrator / [redacted] designed to cut the eingine off when the vehicle had reached its program/spped. I^N this instance the accelorometer failed to perform the required task.

~~The result was an eccentric orbit and ecceptionally~~

The result was that the Agena followed an eccentric path and took an exceptionally long time to circle the earth, about 104 ~~103.7~~ minutes ~~to be~~. The 104-minute period exceeded the vehicle borne timer's capabilites. to react to earth bound ajustment commands. (L vol 1) In addition, the eccentric orbit confused the vehicle's guidance and control system resulting in the premature exhustion of the control gas. The result was that the vehicle was in an improper attitude at the time of capsule ejection. (MSP Q Dec 59)

ROUGH DRAFT

[redacted]

[redacted]

Some improvments in the vehicle components delayed the launching of the next Agena for over a month. (MSP Q Dec 59)

The actual liftoff was another week delayed by several aborthive countdowns on pad 4. Finally on 4 Feruary 1960 the Thor-Agnea soared upward and arced southward, but the Thor's main engine prematurely shut down resulting in the booster velocity being 4,000 feet per second less than normal at the time of Agena separation. In addition, the Agena's engine shutdown prematurely becuase of a malfunction in the helium pressurization system.

[redacted]

Either of these mishaps would have prevented the vehicle from achieving orbit.

Undaunted within two weeks the Douglas crew [redacted] launched another Thor-Agena, this time from pad 5. The countdown was smooth and the launch [redacted] however, immediately after liftoff the Thor began to oscillate and [redacted] when the soaring hardware began to deviate from its program flight path, the range safety officer pushed the electronic destruct button. (MSP Q Feb 60; L vol 2)

ROUGH DRAFT

[redacted]

Two simultaneous explosions occured within the flying hardware verifying that both the Thor and the Agena destruction systems were operating (L vol 2) [redacted]

Some of the resulting debris fell close enough for recovery and examination. (MSP Q Feb 60)

The next launch had been scheduled for mid-March but the Air Force delayed the flight for a month.in order to survey the situation. Again from pad 5, the Douglas crew launched a Thor-Agena combination into the sky, 15 April 60 again at the climax of only one countdown. but this time the Agena went into a fery satisfactory orbit. The battery auxilary power supply lasted through the twenty-sixth orbit and attitude and control system functioned extremely well, resulting in excellant satellite stablisation. Telemetry iddicated that the recovery capsule ejection failed on the seventeenth pass. but that the re-entry trajectory was probably too hight.since spin rocket firing was not verified. This was the first orbiting Agena to carry a dual-feqency doppler beacon and four optical tracking lights. The [redacted] accuracy of the radar system could be tested

ROUGH DRAFT

in comparison, [redacted] [redacted]

As a result of the recovery failure, the Air Force made a greater effort in the testing of the re entry system. The Air Force was intiated a program to test xxxthe components. (MSP Q May 60).

An attempt to launch the Thor-Agena space system from pad 4 occured the twelfth time on 29 June 1960. After some minor countdown technical delays the hardware blasted off into the afternoon sky. The Thor and then the Agena xxx operational sequences were normal through the cutoff of the second stage engine. Nevertheless, the vehicle failed to achieve orbit. Telemetry and subsequent investigation indicated that the vehicle was in an improper pitch down attitude during engine operation causing the vehicle to reenter the atmosphere. due to a malfunction in the horizon scanner (mo rpt June 60)

Subsequent investigation showed that the satellite telmeter transmitter interfered with RF and prevented the horizon scanner to perform properly. (MSP Q Aug 60)

ROUGH DRAFT

[redacted]

[redacted] Littlefield, Agena Story May 63

The thirteenth liftoff from Vandenberg occured on 10 August 1960 at the climax of one countdown attempt.

All events occured nearly as programmed. Thor trajectory and speed were within the limits of toleration and the Agena performance was very close to that which was programmed. Following the burn out of the Agena engine, the vehicle reoriented itself into a nose aft attitude. On the seventeenth [redacted] orbit, 26½ hours after launch, the Alaska tracking station verified that the satellite had pitched down, and [redacted] that is there was a capsule ejection, spin, retro firing, capsule de-spin, and thrust cone ejection.

ROUGH DRAFT

All aircraft and ships of the recovery force that picked up the capsule's radar beacon began moving toward the signal. One C-119 saw the capsule hit the water and relayed the information to a nearby ship, who dispatched a helicopter to the scene. [redacted] With the help of a frogman [redacted] helicopter was able to retrieve

[redacted] the capsule from the chopy waters and returned it safely to the mother ship. Subsequently, the capsule was delivered to Washington for public view as a historic object, the first man-made object recovered after a sustanined period in orbit. (mo rpt, Aug 60; ESP Q Aug 60)

After this exhilerating experince, the launch crew threw another Agena on 18 August. into orbit. Actually at one point the countdown stopped for fifteen minutes while the previously launched vehicle passed through the projected flight area. The Thor and Agenacs performances are as programmed until on the first pass over the Alaskan station, telemetry data indicated that the satellite was in an abnormal attitude. However, the satellite stabilized itself on subsequent passes. While on the seventeenth orbit the satellite programmer automatically intiiated the recovery sequence over the north po[redacted] and the capsule [redacted] the atmosphere over the Pacfic and depl[redacted]. A C-119 aircraft, one of the recovery force's, homed in on the capsule's CW beacon signal and visually sighted the capsule in the afternoon sky. On the third pass under the capsule as it plumbed toward earth, the rear hooks of the spacial air-recovery gear snagged the nylon [redacted] e crew carefully rewelded in the chute and

ROUGH DRAFT

[redacted]

capsules and stored them aboard the aircraft for return to the states.

[redacted]

The recovery of these capsules gave the contractor, General Electric, a chance to examine the effects of an actual reentry.

(mo rpt, Aug 60; MSP Q Aug 60)

After a month's pause another Thor-Agena soared into the mid-afternoon sky, rolled to the south, the Agena separated and ascended into a polar orbit. This launch was the sixth consecutive one to require only a single countdown. (L vol 3)

Telemetry data on the first pass over the Pacific indicated that the vehicle was stable and in the programmed attitude but that the control gas consumption was excessive. On the seventeenth pass the vehicle ejected the capsule, but because of the depletion of the gas, the vehicle's [redacted] downward [redacted] did not occur. As a result, the capsule reentered the earth's atmosphere and decended into the choppy waters of the Pacific about 1,000 miles south of the planned impact point. Nevertheless, recovery forces were able to reach the scene.

ROUGH DRAFT

[redacted]

[redacted]

The Hawaiian station tracked the capsule until [redacted] the atmoshere's ionization particles enveloped it.

From the [redacted] tracked path, a computer [redacted] revised the [redacted] predicted impact point and [redacted] aircraft and one recovery ship rushed toward the point. The first aircraft [redacted] in the area picked up the capsule's radio signals and thirty minutes later a second airfraft sighted the capsule bobbing up and down in the water. The aircraft dopped marker beacons, strobe lights, smoke bombs, and aluminum dye to mark the area. The next morning a Coast Guard amphibian arrived but did not land becuase of rough seas. Because of the worsening sea and weather conditions plans were abandoned to drop [redacted] parachutists and a raft. [redacted]

The capsule began to list and ride low in the water and by afternoon disappeared from sight. (MRP Q Aug 60; mo rpt Aug 60)

ROUGH DRAFT

[redacted]

[redacted]

DM-21 Thor-Agena B

[redacted]

During 1960 both Douglas and Lockheed had improved their respective products and [redacted] subjected the new designs to flight tests beginning on 26 October 1960.

Prior to countdown workers had to modify some of the ground support equipment, particularly for the Agena. The Agena B was six feet longer while the new Thor was five feet shorter, som making the combined length a foot longer thatn the old combination.

The morning countdown was normal and the new combination lifted off the pad at noon. and rolled southward as programmed, but instead of separting from the Thor and ascending into orbit the Agena plunged back to earth with the booster.

[redacted]

Telemetry data showed that a malfunction in the Agena timer prevented sepration mechanisms from operating properly.

[redacted]

ROUGH DRAFT

[redacted]

A chance to dispel the gloom cast by the ignominious fate of the first Agena B flight was at hand on 12 November. Problems with ~~x/Ground equipment at the pad forced a hours cancellation on the previous day~~. After a one day delay due to technical difficulties with pad equipment, the Dm-21-Agena B combination zoomed into the upper reaches of the atmosphere, and after turning southward, the Agena successfully separated itself from booster and aseneded into orbit. The ascent was satisfactory except that the injection altitude was slightly lower than programmed and the orbital period was consequently 2½ minutes longer than planned. Extra batteries for auxiliary power and additional gas for attitude control in the Agena B design enabled the Air Force to plan for delayed recovery operations. Previously, all recovery capsule attempts were planned not later than the following day after launch. Now, attempts could be considered for as long a delay as four days. Consequently, the flight plan called for a recovery on the thirty-second orbit which would occur in daylight hours over the desired area in the Pacific.

ROUGH DRAFT

The extended satellite period had little effect on satellite [redacted] operation or the recovery except to make the alternate pass, the thrity first more desirable than the following one.

[redacted]

After nearly 51 hours in orbit, Capsule ejection [redacted] sequence was near normal and redovery [redacted] forces were scattered in the predicted impact area. A C-119J aircraft made initial contact with the capsule's transmitter and a few minutes later another craft spotted the parachute and capsule descending through the air. On the second pass under the falling apparatus an aircraft successfully snaged the payload. (mo rpt Nov 60; MSP Q Nov 60)

Although the two flights tested the new configured harware provided by Douglas and Lockheed, neither the MDM-21 nor the Agena B had the higher thrust engines. The Air Force had planned flights using the higher thrust engines, following four flight tests with the less adavanced models. However, by December 1960 the higher thrust configurations were available and due to payload considerations, the program director decided to intermingle the use of the higher thrust engines with the lower thrust ones. So, on 7 December the contractor's crew launched the first space mission propelled by the high thrust Rocketdyne's MB-3, Block II and Bell's [redacted]

ROUGH DRAFT

[redacted]

[redacted]

Lockheed considered the [redacted] first high-thrust flight the most successful operation [redacted] to date. (L vol 3)

Liftoff and booster operation was normal. The main engine cutoff when the [redacted] configuration was travelling [redacted] southward at 11,080 feet per senond.46 miles above the earth. The Agena engine ignited as programmed and burned for almast 235 seconds, providing a velocity of 25,900 feet per second as it went into orbit. The resulting orbit had a 380 miles apogee and 133 mile perigee and a period of almost 94 minutes. All systems operated satisfactorily, and after [redacted] a lapase of three days and on the fourty-eighth orbit, the [redacted] satellite successfully ejected the capsule. All elements of the recovery force were at their [redacted] prescribed locations [redacted] when the parachute opened, and a C-119J aircraft snagged the falling package on the first attempt. Subsequent to capsule ejection, the ground signals reoriented the Agena to the normal [redacted] orbital attitude. [redacted] Telemetry recorded a stable attitude-on-orbit for the [redacted] two days [redacted] until the Agena electrical powersource no longer had the energy to keep the attitude control mechanisms operating. (MSP Q Fe

[redacted]

ROUGH DRAFT

[redacted]

Both non-recoverable paylaod flights had successful launches on 20 Decmeber 1960 and 18 February 1961. However, on the first flight telemetry indicated that the gas control mechanism had lost all of its before completion of the first orbit gas and that the vehciles had become unstable. The contractor took action to correct the malfunction for future flights. The second non-recoverable lfight was more successful.

One of the objectives of the February flight was to perfrom the first engine restart in orbit. Consequently, the usual 180 deggree yaw turn immediately after orbital injection was delayed until after the first pass over Alaska. [redacted] The Alaska station signaled and the engine reignited, burning for about one second which increased the satellite velocity about 350 feet per second and increased the orbital period by about four minutes. (MSP & Feb 60 marks ____)

(Mins of 54th AFBMC 15 July 1960) dtd 4 Oct 1960

The two non-recoverable payload flights were interspersed between recoverable flights propelled by the higher thrust engines.

ROUGH DRAFT

[redacted]

[redacted]

The flight launched on 17 February 1961 was not only significant because it was propelled by the hight thrust engines but also because it was the first launch using a Bell Telephone Laboratories guidance system in a space launch from Vandenberg. At the pad, Technicians installed the guidance cannisters in the transition section of the Thor, and used a radio antenna and computer installed originally for use in the Titan I testing installation at Vandneberg. Since then the Titan program personnel had abandoned the installation and Bell had improved their antenna ground system so that it could serve launches several miles away as well as those within a matter of yards.

On this launch, technicans provided an open loop circuit for the radio-guidance system. (AFBM Q Mar 61 p24) Until, this time booster trajectory had depended on the Thor's autopilot and programmer. When the technicans established the closed circuit, any slight deviation from the desired path could be corrected.

ROUGH DRAFT

This launch and flight was satisfactory through until the fourth day in orbit. However, technicans determined that a recovery on the sixty-second pass was more desir[redacted] an the sixty-third,

[redacted]

and a [redacted] tracking station sent a signal for the change. Normally, the command would be stored and halfway through the succedding orbit the programmer would skip an orbital sycle. However, the programmer apparently malfunctioned and prevented capsule recovery.

On 30 March 1961 technicans launched for the first time a Thor-Agena combimation guided by the closed-loop Bell Telephone Laboratories radio-guidane system. [redacted]

The Thor had used an autopilot and programmer to perform trajectory movements. With the Bell guidance system a more accurate trajecotry could be had. In addition the [redacted] cannister in the Thor connected by wire to tha Agena which controlled the second stage engine [redacted] ignition, and [redacted] other mechanisms.

The booster performance and Agena separation and engine ignition performed normally, but 20 seconds prior to engine shut off a rapid drop in hydraulic pressure caused the loss of engine control resulting in Agena velocity being less than required to attain an orbit.

ROUGH DRAFT

[redacted]

A week later [redacted] Douglas crew launched another Thor-Agnea combination. The ascent was satisfactory and the Agena was injected into an orbit approximating the one programmed, and reoriented itself with the engine end in the forward position. However, by the tenth orbit the vehicle became unstable due to the exhaustion of control gas. Nevertheless, the vehicle continued to recive siggals from the ground stations.

Prggram managers decided to attempt a recovery during the second day in orbit rather than the fourth. Upon ground command, the vehicle ejected the capsule, but into a new and higher orbit, due to the vehicle's attitude.

Analysis of telemetry data indicated that temperatures beyound the Agena's experience had caused erratic operation of the gas jet control valves which resulted in the rapid expenditure of control gas. To prevent such a reoccurance technicians were to coated the valves with a heat abosrbne material and wrapped them with thermostatically controlled electric blankets. (MSP Q May 61)
(AFBM Q Sep 61 p32)

[redacted] ROUGH DRAFT

[redacted]

Exxxbxxx Exactly two months following the April launch, technicahs launched antoheer Thor-A$_g$ena. The combination appeared to soar xff into the sky and curve woubthward in the usual pattern, but the A$_g$ena failed to attain sufficient ~~velocity boost~~ develop thrust for orbitatl boost. ~~but 147 seconds after lift-off~~ however far beyond the ~~range~~ from the California coast line, however, the A$_g$ena failed to ~~separate~~ from the Thor and plunged back to earth in ~~a ballistic trajectory~~. Telemetry ~~xxx~~ indicated that there was a fire in the ~~Agena's aft~~ area ~~a fired box separated~~.

Txxxx After studying available data technicians believed that ~~a xxx~~ the A$_g$ena's fuel lines leaked and caused a fire to break out in the the aft section. Measures were taken to ~~xxxxx~~prevent this from reoccuring. (MSP 4 May 61)

ROUGH DRAFT

[redacted]

Increasing Launch Rate

[redacted]

During the past two and half years, all Thor-Agena combinations had blated off from one of two launch pads. These flights were becoming ~~During the past year Thor-Agena launches had been becoming~~ more frequent and the Air Forde beleived that the launch rate would gradually increase in the future. The last Thor training launch occured from Complex 1 in January 1960 and the Strategic Air Command had agreed that the Air Force Ballistic Missile Division could use the installation for space projects. However, the complex would have to be modified to accomodate space launches and the Air Force Ballistic Missiles Commitee did not approve any modification until June 1960. At that time the committee authorized the modification of the blockhouse and Pad 1. The estimated conversion cost was $2 million. (AFBMD Dlgt Mtg, dtd Oct 60)

During the ensuing twelve months, Douglas in conjuction with Lockheed altered the the equipment as necessary including the reorientation of the Pad so launches could be made in a 172 degree azimuth(contr-347, a mend 50) (ltr 26 Jul 60)

ROUGH DRAFT

[redacted]

[redacted] Crew Lost at the Cape

~~Finally~~ On 16 June 1961, ~~the first~~ Thor-Agena ~~was launched~~ ~~from~~ from ~~the~~ pad 1, ~~of Complex 1.~~ (MSP Q May 61)

~~the Agena being injected into a proper orbit.~~

The launch, roll and ascent into orbit ~~occured~~ occured in the usual manner as ~~planned~~ planned. In orbit the Agena was oriented and stabilized itself in the usual programmed manner. ~~Capsule recovery began as planned~~

Capsule ejection occured ~~as planned~~ on the second day follwoing the thirty-third orbit as planned, but due to a miscalculation the recovery forces were in the wrong location. ~~Nevertheless, the capsule's electronic beacon signal reached the location and aircraft reached the capsule~~

Nevertheless, the force picked up the capsule's electronic signal and aircraft rushed toward it. Late in the afternoon an aircraft spotted the capsule floating in the water. ~~Para-rescue men inflated their rubber life raft~~ within a few hours Para-rescue men reached the scene, ~~with~~ jumped into the water, inflated a raft, and by nightfall the capsule was safely aboard their raft. The next morning a ship picked up the rescue team and the capsule for delivery back to the states.

(MSP Q Aug 61 [redacted]

ROUGH DRAFT

Chapter 5

AGENA D [redacted]

Since February 1959 the Agena flown orbited appeared in different configurations in order to meet different program requirements. In an effort to cut down costs, As erarly as September 1959 Lockheed at Sunnyvale and the Air Force in Los Angeles have discussed the feasibility of standaridizing the vehicle. (ltr 29 Sep 59) At the first the

The difficulty in establishing a stanadrad second stage behicle was the diverstiy of requirements demanded of the using programs. In early 1960, Lockheed noted "six groosly dissimilar operational functions at three different altitudes on orbits varying from polar to equatorial. Additionally, the versateil Agena must accomodate boosters of radically diff

different capabilities and permit adapatations for widely differing control refinements." Rather than attempting to design one absolute structure The very scope of the programs precluded the single do-all vehicle as an ideal solution, yet Lockheed agreed that the vehicle should be simplified . (ltr 4 March 60)

At first the best that seemed feasible was the fabrication of three or four identical [redacted] ries.

By 1961 the Air Force determined that it had much to gain by a basic

ROUGH DRAFT

redesign of the Agena B and regid configuration control therdafter.

In lieue of this action toward
So Lockheed initiated a design study ~~in [redacted] to~~ achieving

a standard Agena vehicle ~~for ascent into orbit~~ to serve all known

requirements. (ltr 6 Nov 61)

As the prelimianry design (~~study~~) progreesed, two sailient points emerged.

It appeared feasible and desirable to design the structure so as to

accept optional equipment which could be ~~[redacted]~~ installed for specific

missions. Secondly, ~~the~~ in order to ~~obtain [redacted]~~ improve

reliability and maintainability as well as receive economic benefits,

~~it appeared feasible and desirable to improve~~ the product should be improved

the manufacture of the first few. (ltr 6 Nov 61)

Following presentation in October
In September, the Air ~~[redacted]~~ Staff, Under Secretary of the Air Force Chayrk,

~~and the~~

and the Deputy Director of Defense Research and Engineering,

Rubel approved this standardization concept.
Reubal. [Reubal Rubel place a further qualification that the concpet be

reviewed further after ~~the~~ Lockheed completed the design.]

(ltr 2 6 Nov 61)

~~[redacted]~~ ROUGH DRAFT

Meanwhile, The Space Systems Division proceeded to let a CPFF letter contract [redacted] on Lockheed for the design, development, and production of 12 Agena D [redacted] vehicles which would be standard in nature and capable of being used with a minimum degree of change in the various programs. The first one Agena D was to a launch ~~flight should~~ be ready for flight in January 1963. (Agena D stauts rpt, Aug 62) (Htr 18 Sep 61) (contr -21)

However, this schedule was soon to change.

On 17 October 1961, Charyk appointed a fourtman committee headed by Clarence L Johnson, Vice President of Lockheed to "investigate ways and means for improving the reliability of the Agena vehicle and recommend improved procedures for getting the standard Agena D into earlier operation." A week later the committee reported its findings to Charyk. It proposed procedures which it thought would result in a June 1962 first launch, and the possibilty of starting a standard prduction of five per month beginning in January 1963.

ROUGH DRAFT

The committee found the organization structure of the company at Sunnyvale and the method of subcontractors acceptance testing of subsystem equipment at Sunnyvale rather than at the subcontractors plants seriously imediate adv against a reliable vehicle. [redacted] Mil Tatel ?

The commitee belived that the June 1962 launch date could be [redacted]

the Air Force met
if/fifteen conditions. were These were:

1. A DX priority should be assigned the Agena "D" program.

2. The engineering system should be similar to that of the U-2, requiring only engugh drawings to tool, build and service the vehicles.

3. An early and final configuration freeze is necessary. [illegible] adjacent to the [illegible] area.

4. The engineers should be located in a secure area immediatly adjacent to the tooling and manufacturing area.

5. A rapid drawing release system (24 hours maximum) from the project engineer's approval to the manufacturing group is necessary.

6. Fundigg should be ~~xxxxxxxxxx~~ adequate and timely.

7. Delete technical directive meetings invoaving large groups. Have Air Force personnel working close engough with the LMSC /Lockheed Missile and Space Company/ project engineer so that formal meetings are not required. Keep extraneous visitors away.

8. Reasonable overtime ~~xxxx~~ should be approved. In some cases, this may come after and not prior to its use.

9. Air Force approval of vendor selection ~~xxxx~~ should be furnished on the spot at Sunnyvale. When single source procurement is necessary, a short written record of why this was done must be kept on file.

10. Tooling should be of the simplest type that will give interchangeabiaity, as stated in the basic Agena "D" specification. No tool drawings or outside approval of tooling should be required.

11. Interchangeability on the first four Agena "D's" will be limited to major structural and equipment items. [illegible]ours, for instance, may require trim to fit.

12. No engineering analysis reports should be required. Revert to the old system of using the basic engineering reports, which furnsih comparable data.

13. Another pad should be made available at Vandenberg (Pad #2 - Complex 75-1).

14. The WSPO /weapon system project office/ and LMSC /Lockheed Missile and Space Company/ should review the specification problem together and agree at the configuration conference to reduce the number of specifications involved to the minimum compatible with the Agena "D" mission. It should also be noted that many items common with the Agena "B" will be used on the "D", and have already been qualified to exisiting specifications.

15. The /Air Force/ Program Director should be responsible for, and delegated authority for, all Agena "D" functions, including C&C /communications and control/ flight hardware. No C&C T-D's /technical directives/ should be required.

[redacted]

RANCH DRAFT

[redacted]

Knowledgeable persons with the Space Systems Division were dubious about the proposed program. For one, if the Air Force was to pursue a fixed price contract following the initial standardization, it would be necessary to have formal model specifications, drawings and documentation for both the vehicles themselves and any specialized tools. (Blum 6 Nov 61) The drastically compressed time schedule would make it difficult it not impossible for the necessary doucumentation to be accomplished on the vehicle, and according to the recommendations, formal tool design would not be required. (Evens 6 Nov 61)

Nevertheless on 7 November 1961, Charyk approved the Johnson committee proposals, called the "skunk works" procedures. (9 Nov 1961) (Proj Plan 22 Dec 61)

ROUGH DRAFT

[redacted]

[redacted]

In pursance to these new guidelines, the Air Force headquarters directed the Space Systems Division to prepare an Agena D program plan to be presented in Washington. (TWX 30 Nov 61) / The divsion's plan included both the initial development of 12 flight vehicles and the continued production of more. The division estimated that the program would cost $48.9 million for fiscal year 1962 and $88.5 million for 1963. (abbreviated plan, dtd 22 Dec 61) . The Air Force Systems Command headquarters approved the plan on 2 January 1962 and Charyk approved it the next day. (memo 5 Jan 62)

It was the intention of the Director of Defense Research and Engineering that the Agena D program be budgeted as a separate line item. However, principally because the using programs had previously been funded for fiscal 1962 (including Agena progurment), it was not unitl 31 May 1962 that the Air Force headquarters converted funds to cover the Agena D development, engineering, and industrial facility requirements as a separate budgeted program. Until that time, Agena D buyers were operating on a system of reimburaable funds whereby the using program would pay the Agena D program for procuring services & hardware. (TWX 8 Dec 61; ltr 19 Dec 61; ltr 2 Apr 62; ~~TWX 1 Jun 62~~; ltr 11 Jan 62; ltr 30 Apr 62; TWX 1 Jun 62)

[redacted]

ROUGH DRAFT

[redacted]

On 27 November 1961, Chark had directed contract that work proceed on a cost plus incentive fee basis [redacted] for the initial 12 Agenat Ds the remaining one be procured on either a fixed price contract or a fixed price incentive fee one. (memo 27 Nov 61) So the Space Systems Division began to negotiate to change the letter contract, cost-plus-fixed-fee to ate new type.

Lockheed's made first fee proposal on 15 December 1961 which the Air Force would not accept.
Negotiations dragged on between the Space Systems Division and Lockheed concerning the development contract as a result of proposals and counter propasals revolving around a formula for incentive fee (memo 14 Feb 62) (ltr 22 Mar 62)

Finally in April, a defintive agreement was reached between the contractor and the government which specified a target fee of 7-2/3 per cent of cost [illegible] target fee of $3 million.(contr -21)

ROUGH DRAFT

By this time over half of the vehciles were in process of being manufactured. (TWX, Mar 62) The fact that as a matter of policy the division had would not obligate more than 60 per cent of appropared funds on a letter contract, may have influenced the concludion of negotiations. (ltr 25 Apr 62) (ltr 14 May 62)

[redacted]

The division determined it practival to issue a straight fixed price for 39 follow on vehicles con ract since the only cost data available would be derived from the first 12 standard vehicle contract. which incluedes a large portion of non-recrruing costs of design, tooling and test equipment, plus changes in the development process. (ltr 22 Mar 62)

In April Ritland worte to Schriver stating that a clarification was needed as to the Air Force position on whether or not the origianl 15 rule used to develop the first twelver A enas D were to be continued inoto the productin phaxes. Johnson ahd Ritland understood this, but apprently instruction have gone through normal AF channels negating this appraocha.(ltr 25 Arp 62) Carlton Kelly also

AF accepted first standard chassis on schedule (ltr 25 Arp 62)

Following the December 1961 issuance of the letter contract for the follow-on production of the 39 vehicles, the contractor and the government negotiated a [illegible] fixed-price incentive redeterminable contract, a reavaluation would occur at thetime of delivery of the twelfth chassis. (TWX 10 Aug 62; TWX 24 Aug 62) However, in

ROUGH DRAFT

[redacted]

a fixed price incentive type contra t would be best (TWX 13 Sept 62 to OSAF; TWX 13 Sep 62 to AFSC) and nggotiation were completed shortly thereafter establisheing [redacted] as the target price. (ltr 14 Nov 62)

ROUGH DRAFT

[redacted]

[redacted]

Organization

Due to the highm priority that Washington placed on the Agena D program, the entire orgranizational concept was to streamline proecedures and to limit the number of people directly participating in the program. In November General Schriver directed General Ritland to establishm within the Space Systems Division a spparate Agena D program office, directly responsible to Ritland. The office should include engineering and contract administrative functions. With Shhriver's approval, Ritland chose Colonel H B Kucheman to be the program director. In addition Schriver authorized direct communicatio n between Kucheman's office and General Holzapple's office at Air Force headquarters for contact at that command level or higher.

(ltr 24 Nov 61; ltr 20 Nov 61)

Lockheed Missile and Space Company established a separate organization for the Agena D porgram headed by Fred O'Green and physcially located ma apart from the rest of the Sunnyvale plant. O'Green had broad comprehensive authority including control over operations normally organized on a plant-wide functional basis.

(S-01A staus rpt, Aug 6[redacted]

ROUGH DRAFT

[redacted]

Personnel of the Space Systems Division's program office established what amounted to temporary residence at Lockheed Agend B's fabrication facility. These officers particiapted with O'Greenraters and his personnel in all meetings, discussions, evaluations and decisions at the contractor's facility. In addition to the Space System Division personnel, a selected few specilists from the Air Force Plant Representatives office participated in contractural arrangements under Colonel Kucheman's direction.. In this kind of relationship, the Air Force program director was actually involved in what amounted to a continuing fact finding operation with the contractor's program manager. (ltr 13 Aug 62)

Only the few people from the Space Systems Division, Air Force Plant Representativess office, and Lockheed who were had responsible roles in the day to day operation of the Agena D program had access to a restricted area ajacent to the Agena D assembly line.

In order to help Air Force and Lockheed engineers determine a suitable design, the contractor fabricated several test vehicles and mockups.

[redacted]

ROOM DRAFT

[redacted]

improvement
Since reliability as well as standardization were objectives of the Agena D development phase, Lockheed fabricated several test vehicles and mockups.

A propulsion test vehicle was used to proof test a new orifice pressurization system and the dual start capability of the rocket engine, A structural test vehicle was used to qualify forward equipment rack and aft structure, and A thermal test vehicle was used to verify environmental acceptability of the design. (ltr 13 Jun 62)

An "development test vehicle" was completed on 31 March 1962 and Lockheed hot fired it for the first time at Santa Cruz on 23 May 1962. (ltr 13 Jun 62)

The development test vehicle might be used for installing, qualifying, and when necessary, hot firing, ~~(program possible and component improvement~~ Potential improvements ~~modifications~~ in supprot ~~sxx~~of all using programs. (ltr 13 Jun 62)

As part of the standardization, Air Force intended that automatic checkout equipment would be developed and could be used beginning with the nineteenth chassis. For all vehciles prior to that one, Lockheed used manual checkout equipment. However, the automatic equipment only applied to the standardi[redacted]

ROUGH DRAFT

[redacted]

A flyable Agena D consisted of the standard chassis plus certain optional equipment. In addition programs would have hardware peculiar to their mission.

The objective of the development contract was to perfect one standard chassis. According to plan, Lockheed would checkout standard component parts, assemble the parts into a chassis, checkout the entire chassis and present this item to Air Force Agena personnel for accetpance. Lockheed would move the chassis to an adjacent building and install optional and mission peculiar equipment. The contractor would then manually checkout the entire vehicle for acceptance by the using program personnel. (ltr 28 Dec 61)

Thus, as General Rita correctly observed, in order to have a usable vehicle, two checkout and acceptanne procedures were necessary. (memo 25 Apr 62)

[redacted]

ROUGH DRAFT

[redacted]

For the first twelve [redacted] Agena D chassis, O'Green, the Lockhaed program manger, was responsible for controlling the configuration. However, Air Force managers promulgated overall guidlines. In order to allowing for some experimentation in design, all the parts of the first several chassis were not interchangeable. In April, Colonel Kuchechanox asked O'Green to standardize the configuration beginning with the sixth chassis to be deliverd to the Air Force for acceptance. ~~The contractor wanted to avoid simultaneous changes in the design beyond the strengthening the forward and aft equipment racks and~~

(memo 18 Apr 62; prog rpt 13 Jul 62)

Lockheed had albeady redesigned the intial "standard" configuration at least twice. (memo 26 Feb 62) and the colonel wanted to make sure that a sutiable engineering drawings, specifications, and documentation procedures accompany the 13th chassis when ~~would be ready for the acceptance of the thirteenth vehicle, the first to be fabricated under the production contract.~~ the AF for acceptance

Effective 1 July 1962, a The Space Systems Division established a configuration control board [redacted] representatives from using Air Force and

ROUGH DRAFT

[redacted]

NASA programs. [redacted] and headed by an offtiver in the Agena program office. The board was responsibile for the acdeptance of all vehicles produced under the production contract and the determination of any future configuration chagges.
(mw prog rpt 13 Jul 62)
(ltr 11 July 62; ltr 9 July 62; ltr 25 Sep 62)

A team from the Board The ~~first article configuration inspection team~~ examined the thirtheenth ~~x~~ Agena D, ~~or~~ the first of the production contract~~s~~ in September 1962. Documentation presented to the team by Lockheed was not entirely adequate to define a configuration "baseline." but the team agreed to accept this chassis and the next five with the documentation as presented. ~~The acceptance of the first six production vehicle would be based on specifications which ~~as~~ the the team gave interim approval.~~

Lockheed took action bo make the necessary corrections as recommended by the team and in November the team inspected the ~~ninth~~ nineteenth chassis ~~production unit~~ and determined that the documentation was adequate to define a "baseline" configuration. The team then directed the office of the Air Force plant representative to began accepting the units with the approved ~~to the improved~~ douctmentation ~~specifications~~. In addition, a portion of the inception team inspected each optional kit [redacted]. By

ROUGH DRAFT

[redacted]

[redacted]

Since the ridgid configuration control procedures were not applied before the thirteenth chassis, the Agnea office planned that any marginal performance on the first flights during June and July would be identified so that Lockheed could modify the production package accordingly. (mo prog rpt 13 Jul 62)

In the opinion of General Ritland, the final proof of the Agena D effort would be shown in the flights (ltr 25 Apr 62)

According to the Agena D program plan, using programs would have flown thirteen vehicles from June through December 1962. In reality only five were used and at the end of the year there was no immediate prospect for an increase in the demand.

ROUGH DRAFT

[redacted]

[redacted]

In October 1962, the division made contractual arrangements with Lockheed to store the chassis and associated equipment while were not in use. They were to be stored in a suitable enviornment on a first-in-first-out basis in order to ~~mitigate~~ against aging and weathering. (TWX 12 Oct 62; ltr 2 Nov 62; hist rpt Jul-Dec 62)

~~The division considered guidance modules were safe in storage but asked Lockheed to determine the life expectancy.~~

Storage costs were [redacted] per bird in January 1963 and/Air Force headquarters directed the production rate be cut back to three birds per month. (pro review 26 Jan 63)

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[redacted]

[redacted]

Component Improvement

One philosophy of the Agena D program was the segration of the 39 vehicle production effort from any technical support and component improvement contract. (ltr 21 May 62) Although the development contract provided for some product improvement, the rapidity in which the design was frozen, caused the division to have most of the Agena B qualified components merely in a repackaged form. (ltr 24 Jan 62) The division belived that the componets needed to be developed further in order to better serve current and future program requirements. Following a presentation in Washington by the Space Systems Division, Charyk approved on 25 June 1962 an advanced development program as a line item in the budget. The division estimated costs of $5.5 million for fiscal 1963 which the Air Force headquarters approved. (ltrs 25 June 62; ltr 27 June 62)

Nevertheless, the division was obligated to defend plans to improve particular components before the Air Staff. (TWX 30 Nov 62)

One of the most important advanced development requirements was for the improvement of the Bell engine for the Gemini program. (TWX 28 Sep 62)

[redacted] Agena D used the

For the standard Agena D configuration, engineers had adapted the 16,000 pound thrust dual start engine which had propelled most of the AgenaBs in flight. Except for a change in the turbine exhaust duct the improved Agena B and the first Agena D engines were essentially the same. However, in order to insure positive identification the Air Force designated the new model LR81-Ba-11. (ltr, 20 Jul 62; ltr 3 Aug 62)

During 1962 the National Aeronautics and Space Administration expressed the need for a multiple start engine in the Agena. The civilian space agency wanted to use the Agena as a rendezvous vehicle in the Gemini program but in order to be able to rendezvous with another orbiting vehicle, the Agena would have to be able to make fix adjustments in its flight path. The Space Systems Division directed Bell, through Lockheed, to make the necessary improvements to meet the Gemini requirements but at the same time design the engine to be compatable with the Agena D. After the 1963 tests, the division might adopt the multiple start engine as the standard one for the Agena D. The principal task at hand was to simplify the starting system by removing the solid ullage rockets and controlling the [redacted] the gas generator by valves alone. (ltr 20 Jul 62; ltr 25 Jul 62; TWX 2 Aug 62)

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Chapter 6

THRUST AUGMENTED THOR

During 1959 and 1960, Douglas Aircraft Company was analyzing the basic Thor booster to determine how its capacity for heavier objects into orbit and at higher altitudes might be achieved. From these studies came at least two unsolicited proposals. One involved an engine with greater thrust and propellant tankage with increased capacity. However, since the Air Force would have to develop a new engine, the pursuits of such a concept would have been relatively expensive. In June 1961, Douglas revealed a more expedient way of increasing booster capability. This method would be by the use of the standard DM-21 booster with three solid propellant rocket motors strapped on the engine rectangular frame. These solid rockets were available from Thiokol having been used as the second stage of the Air Force's Blue Scout launch vehicle and originally developed for the Army. (D rpt, June 1961) [redacted] EM-33-E2 [redacted] and other programs. [redacted] (Ltr, 8 Feb 62)

Each of the solid rockets had a thrust rating of 54,000 pounds; these three rockets combined with the DM-21 propulsion system would give about 300,000 pounds of thrust. [redacted]

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[redacted]

Agena payloads were getting heavier and heavier until it became clear that many future program requirments would be beyond the capability of the 170,000 pound thrust of a single Thor booster. (memo, 15 May 62 atch to ltr 4 May 62) On 27 February 1962, a program director asked that Douglas make a two month study and in coordination with Lockheed, define more precisely the performance and design of the propesde thrust augmented Thor. (ltr 27 Feb 62) Following the detailed study, the program director felt that since additional thrust would be needed in the immediate future, the proposed appreach was the only one feasible. On 26 April, he requested the Space Systems Division's Thor booster office to provide a new hardware combination ready for the envisioned for the first flight seven months hence and for nine similar flights during the following year. (ltr 26 Apr 62)

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The requesting program office was providing the necessary funds estimated to amount to $3.35 million. For budget purposes, the Space Systems Division estimated that after the first unit, each thrust augmented Thor would cost $700,000 or $250,000 more than the standard DM-21. (ltr 9 May 62) Launch costs would be another $700,000 or $100,000 more than a DM-21 launch. (hist rpt,

Tests

In early July 1962, the Thor booster office asked Aerospace Corporation to be technical consultants for the thrust augmented Thor integration. (ltr 24 Sep 62) Operating under an extremely short lead time,

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[redacted] the booster office procured the solid motors directly from Thiokol (contr - 148) and negotiated an agreement with Douglas. The Thor airframe contractor whereby the firm would provide a prototype thrust augmented configuration by modifying a DM-21 booster, attaching the solid motors to it, and testing the new combination at the Army's Redstone Arsenal. (contr -152) Douglas modified the DM-21's flight control system, increased the [illegible] instrumentation, and installed brackets on the aft section of the booster frame. Each set of brackets was to hold in place one of Thiokol's 7,500 pound motors. Douglas demonstrated the capacity of the Thor to support such weights and verified the suitability of the booster modifiaations by a series of vibrations and load tests.

In connection with the aft brackets there were a number of explosive bolts designed to sever the rockets from the booster frame upon a programmed signal. Static firings at the arsenal showed that this severance mechanism needed to be refined. In additon from scale model tests, engineers were able to improve the timing of the severance. By [illegible] By waiting a minute after the [illegible] burnout the Thor attitude would be in a better position to avoid contact with cases as they would fall away. [redacted]

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[redacted]

The Space Systems Division was also concerned about the performance of the engines and the effects of their exhausts in the new enviornment. In order to reduce the probability of combustion instability in the main engine, the divisinn directed Rocketdyne to install a baffled injector in the MB-3, Block II engine. The modification had been successful in similar engines used by the Atlas bboster. (TWX 1 Aug 62)

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[redacted]

Production, Delivery and Launch

Space Systems Division planned to have Douglas produce the neceesary modified DM-21 boosters in a normal assembly line fashion. Howeger, the new engineering design package generated from tests would not be ready immeidately and in order to expedite early delivery of the first three, the division contracted with Douglas to DM-21 produce three standard DM-21 boosters and then modify them after they came off the assembly line.*

(* In addition, two Ablestar configured Thor boosters were to be similarly modified))

(ltr 11 July 62; contr - 186)

In the past Douglas and Lockheed shipped to Vandneberg the first and second stages from Santa Monica and Sunnyvale respectively. Now, Thiokol was obligated to ship motors in monthly increments beginning in September 1962. (contr -148) to be tempo rarily stored and then mated with the other airborne hardware at the launching pad.

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[redacted]

Lack of a firm decision on the Class of explosives, by the Armed Force Explosive Safety Board precluded the completion of a storage facilities for the solid rockets in time for the first launches. Air Force personnel had to wait for the board to rule whether the rockets could inadvertently exploded or burn. This would determine the nature of the storage as well as the distance from the pad. the building in which they could be housed in. (ltr 13 Jul 62)

In the meantime, managers made arragnements to hosue these rockets temporarily in an iglooo type construcion used by the Blue Scout program.

The first of the cylindriaal rockets, 2½ feet in diameter and 21 feet long, weighing 7300 pounds, were scheduled to arrive at Vandaaberg in September. (TWX, 1 June 62; memo 11 June 62; memo 13 Aug 62)

Finally in October the safety board ruled that these rockets would not inadvertenly explode and in February construction began on a prefabricated metal building near the Thor launch pads.

(interview with Capt J B Rauhut, SSNF, 6 Mar 63)

Douglas [redacted] provided additional ground equipment to accomodate [redacted] configuration at existing Thor launch complexes and readied Pad 5 for the first flight.

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The first modified DM-[redacted] finally arrived at Vandnesberg in December (hist rpt, Jul-Dec 62) and the programme director hoped for a launch within another month. Technical difficulties caused delays including several postponements on the pad. Finally on 28 February 1963, the new booster combination rose off its pad pushing an Agena D into the sky. However, the vehicle veered off course and the Pacific Missile Range safety officer pushed the button to destroy the flying hardware. On the pad when the Rocketdyne engine appreached liftoff thrust, a current passing through installed circuits was designed to ignite the three solid motors. However, in this case, there was an improper connection which cuased one solid motor not to ignite. Thus an Agena was inadvertantly lost on what was in essence the first flight test of this particular hardware combination.

Despite the initial setback, undoubtedly the thrust augmented Thor would be used as a booster for future space flights requiring thrust ratings between that of the DM-21 and the more powerful, but more expensive Atlas. (info frm SSE) These la[redacted] will be the only known ones utilizing a combina tion of liq[redacted] and solid propellant motors. (hist rpt Jan-Jun 62)

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Chapter 7

CONCLUSIONS

During the span of seven years---1956 through 1962 in the Los Angeles area, the Western Development Division, renamed the Air Force Ballistic Missile Division, and reorganized as the Space Systems Division, was responsible for the day-to-day management of the Air Force statellite development. However, during the entire time the purse strings were held tightly in Washington and all major technical and managerial decisions were approved by the Department of Defense, or during 1958 and 1959, by the Advanced Research Projects Agency. These administrative arrangements were demonstrated in the go-slow attitude typified by Assistant Secretary of Defense Quarles in 1956 and 1957, the reams of numerical orders published by the special defense agency, during 1958 and 1959, and the continual dialogue between the Los Angeles project personnel and the Defense Director of Research and Engineering, from 1960 through 1962.

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[redacted]

[redacted]

Los Angeles space program managers approached the satellite systems development by determining what components were available and which ones needed to be developed. By this method the managers could shorten overall development time and reduce costs. However, some component development was inherent in the purposes behind the early satellite concepts. Early objectives included the establishment of ground satellite communications and data processing techniques, and the development of a recovery system. The outer shell of the early recovery capsules were the by-products of reentry vehicle tests; but another area which had to be developed was in the satellite attitude control system.

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[redacted]

[redacted]

Nevertheless, Air Force satellites owe a great debt to other programs because of the components and systems which were made available in various stages of development. Of all the systems which were available to Lockheed the most important was the satellite engine which Bell Aircraft Company had been developing for the B-58 program. This fact is not to say that many refinements had to made and that improvements were desirable. Bell redesigned the engine for a higher energy fuel, later increased the fuel burn time and established a restart capability, and then went on to increase the thrust.

Following Sputnik, the decision to use the Thor as a booster was predicated on the fact that the missile would be available before the other Air Force alternative, the Atlas. Nevertheless, space project managers were not satisfied with the Thor missile and so consequently redesigned the frame and increased the engine thrust, and selected what they thought was an improved fuel developed in the Navaho program. In a further effort to increase the first stage booster capacity, the space program managers augmented the Thor with solid rockets used by the Air Force [redacted]

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[redacted]

the Air Force Blue Scout program and the National Aeronautics and Space Administration and developed by the Army.

[redacted]

Both the airborne cannisters and the ground antennas and computers of the Bell Telephone Laboratories radio-guidance system had proven themselves before a space program manager requested, in July 1960, that the guidance system be used to provide greater trajectory accuracy on the Thor-Agena launches from Vandenberg Air Force Base. The system had successfully guided early Titan and Thor missile test flights and Thor boosted reentry vehicle test flights and there was available ground equipment at Vandenberg installed by the Titan program.

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[redacted]

[redacted]

In great part due to the engineering and managerial skills of Air Force space program personnel in Los Angeles, the Thor-Agena flights have become gradually more successful. At first the primary concern was for the Agena to achieve a polar orbit, later there were difficulties in the ground-satellite communications, and still later in the attitude control, and capsule ejection and reentry system.

From February 1959 through December 1962, the Air Force launched satellites, 60 were Thor-Agena flights. Althoughgh either the first or second stage may be flown in combination with anohter configuration, by farm the most Air Force satellite launches have been with the Thor- Agena combination. The Thor-Agena combination has proved the back bone of the Air Force space program.

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[redacted]